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Research Article

THE ROLE OF MOTHER TONGUE-BASED MULTILINGUAL EDUCATION IN ENHANCING EXECUTIVE FUNCTIONS IN BALINESE CHILDREN

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Abstract

This study investigates the role of Mother Tongue-Based Multilingual Education (MTB-MLE) in enhancing executive functions among Balinese primary school children. The research stems from the growing recognition that early bilingual and multilingual experiences influence cognitive control, working memory, and attentional flexibility. The study aims to determine how instruction that integrates Balinese, Indonesian, and English affects children's cognitive development, particularly their executive functioning skills. Using a mixed-methods design, data were collected from 120 students across three primary schools implementing MTB-MLE programs. Quantitative assessments of inhibitory control, cognitive flexibility, and working memory were complemented by qualitative classroom observations and teacher interviews. The findings revealed that children educated under MTB-MLE demonstrated significantly higher performance in attention-shifting and problem-solving tasks compared to peers in monolingual instruction. Qualitative data supported that the use of the mother tongue enhanced comprehension, participation, and self-regulation. These results suggest that multilingual education not only preserves linguistic and cultural identity but also strengthens cognitive adaptability essential for academic success. It concludes that policy support for MTB-MLE in early education can contribute to both linguistic equity and neurocognitive development in multilingual societies.

Keywords: Balinese Children, Cognitive Development, Cognitive Flexibility, Executive Functions, Mother Tongue-Based Multilingual Education

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INTRODUCTION

Language serves not only as a medium of communication but also as a fundamental tool shaping cognition, identity, and cultural continuity. In multilingual societies such as Indonesia, language policy plays a vital role in determining how children develop cognitive and social competencies from an early age (Fuentes-Merino, 2025). The Balinese context, characterized by a dynamic interaction among Balinese, Indonesian, and English languages, provides an authentic environment to examine how linguistic diversity affects children's cognitive growth (Carmo, 2025). The implementation of Mother Tongue-Based Multilingual Education (MTB-MLE) in Bali aims to strengthen early literacy and comprehension by grounding learning in the child's first language before gradually introducing national and global languages (Chuang, 2025). Such an approach aligns with UNESCO's advocacy for linguistic inclusion as an entry point for equitable and quality education.

The relevance of this educational model extends beyond linguistic preservation; it influences the neurological processes underlying executive functions such as working memory, inhibitory control, and cognitive flexibility that are central to learning and adaptive behavior (Y. C. Chen, 2025). Studies in psycholinguistics and cognitive neuroscience reveal that bilingual or multilingual experiences may enhance cognitive control and attention regulation. However, despite these findings, the specific interaction between MTB-MLE practices and executive functions within local sociolinguistic settings remains underexplored (Guede-Rojas, 2025). The Balinese educational landscape offers a valuable lens to investigate how early multilingual exposure contributes to the development of higher-order cognitive skills.

The urgency of this investigation stems from the educational disparities that emerge when children from linguistic minorities are compelled to learn exclusively through dominant languages (Bai, 2025). When instruction neglects the mother tongue, learners often struggle with comprehension, motivation, and identity integration. Conversely, using the local language as the foundation for learning has been associated with improved cognitive performance, socio-emotional well-being, and metalinguistic awareness (Lehrman, 2025). These considerations frame the importance of analyzing how MTB-MLE not only facilitates literacy acquisition but also strengthens the cognitive systems responsible for executive functioning in Balinese children.

The central problem addressed in this study concerns the limited empirical understanding of how mother tongue-based multilingual education affects executive functions among primary school children in Bali (Q. Chen, 2025). While the theoretical link between bilingualism and cognitive control has been widely discussed in global research, most existing studies are conducted in Western contexts or among balanced bilingual populations (Zhang, 2025). The sociocultural conditions of Balinese children who navigate complex linguistic environments shaped by heritage, national, and foreign languages demand context-specific investigation. The issue is not simply whether multilingualism enhances cognition, but how the structured integration of the mother tongue in formal instruction contributes to executive function development.

Educational policies promoting MTB-MLE in Indonesia have often emphasized linguistic preservation and inclusion, yet empirical evidence regarding its cognitive benefits

remains scarce (Sun, 2025). Many schools face challenges in implementing effective multilingual programs due to inconsistent teacher training, lack of appropriate learning materials, and varying parental attitudes toward local languages. Consequently, the cognitive implications of these pedagogical practices are underreported (Jakubow, 2025). This research addresses the question of whether sustained use of the Balinese language in the early stages of education enhances cognitive flexibility, attention control, and problem-solving abilities compared to monolingual instruction.

Understanding this relationship is crucial because executive functions act as predictors of academic success and lifelong learning capacity (Canilao & De Los Reyes, 2023). Deficits in these cognitive domains can hinder children's ability to manage complex tasks, shift attention, and regulate behavior skills essential for academic achievement in multilingual environments (Velasco, 2025). Investigating how MTB-MLE influences these dimensions may guide educators and policymakers to design language programs that promote both cultural preservation and neurocognitive advancement in young learners.

The primary objective of this study is to examine the extent to which Mother Tongue-Based Multilingual Education enhances executive functions in Balinese children (Bravo-Sotelo et al., 2024). It seeks to evaluate the relationship between the use of the Balinese language as a foundation of instruction and the development of working memory, cognitive flexibility, and inhibitory control. The research also aims to identify the pedagogical mechanisms through which multilingual instruction supports metacognitive awareness and self-regulation in learning processes (Čok, 2024). By combining quantitative cognitive assessments with qualitative classroom observations, the study provides an integrative view of both neurological and behavioral dimensions of multilingual education.

Another objective is to compare the executive function performance between students enrolled in MTB-MLE programs and those taught in monolingual Indonesian-medium schools. This comparative framework allows the investigation to isolate the specific contributions of multilingual experience to cognitive outcomes (Bornman et al., 2025). The study further aims to uncover contextual factors such as teacher competence, curriculum design, and sociolinguistic attitudes that mediate the effectiveness of multilingual instruction (Rajesh & Sharma, 2025). By situating the analysis within the cultural and educational realities of Bali, the research intends to produce empirically grounded insights relevant to broader discussions on multilingual education policy.

The findings are expected to contribute practical implications for curriculum development, teacher professionalization, and educational equity. If the results demonstrate a significant enhancement in executive functions, it will support stronger advocacy for MTB-MLE as a cognitively beneficial and culturally sustaining pedagogical strategy (Arzadon & Abaya, 2025). Ultimately, the research aspires to reinforce the understanding that cognitive and linguistic development are deeply intertwined processes that must be nurtured through inclusive and context-sensitive educational frameworks.

Existing literature on bilingualism and executive functions provides substantial evidence of cognitive advantages linked to multilingual exposure, yet these findings remain inconclusive due to varying methodological designs and sociolinguistic contexts (Premsrirat & Hirsh, 2025). Most research has concentrated on balanced bilinguals in Western countries, where the languages involved often share similar scripts and sociopolitical statuses. In contrast,

little attention has been given to multilingual settings in Southeast Asia, particularly where local, national, and international languages coexist within hierarchical structures. This gap limits the generalizability of current theories to the Indonesian context, where multilingualism operates under different cognitive and cultural dynamics.

Previous studies on MTB-MLE in Indonesia have primarily focused on literacy acquisition, language attitude, and educational access rather than on neurocognitive outcomes. Few empirical investigations have explored the cognitive mechanisms through which the mother tongue influences executive control processes (Adhikari, 2025). Furthermore, most available studies treat language policy and cognition as separate domains, overlooking their intersection in classroom practice. This disconnect highlights a critical research gap that this study aims to fill by integrating psycholinguistic, educational, and sociocultural perspectives in one analytical framework (Lee, 2025). By addressing this void, the current study positions itself as a bridge between language policy research and cognitive developmental psychology. It recognizes that educational interventions promoting linguistic diversity can simultaneously function as catalysts for cognitive growth. The research not only responds to the scarcity of localized data but also advances theoretical understanding by contextualizing cognitive advantages within culturally embedded multilingual systems.

The novelty of this research lies in its interdisciplinary integration of mother tongue-based education, cognitive neuroscience, and cultural pedagogy within the Balinese context. Unlike previous studies that examine bilingual advantages in abstract or decontextualized settings, this study situates cognitive development within real educational environments influenced by cultural identity and linguistic hierarchy (Lumidao et al., 2024). It offers empirical evidence on how structured exposure to multiple languages enhances executive functions among children from a non-Western linguistic background. This focus contributes new perspectives to global discourses on multilingual education by demonstrating that cognitive advantages can also emerge from culturally grounded, community-based instructional models.

The research justifies its importance through its potential impact on educational reform and child development policy in Indonesia. Demonstrating a cognitive benefit of MTB-MLE provides a strong rationale for maintaining and expanding local language programs in early education, countering the growing dominance of national or foreign languages. The findings will inform policymakers, educators, and curriculum designers on how linguistic inclusivity can serve as both a cultural and neurocognitive asset. In addition, the study contributes methodologically by combining behavioral testing of executive functions with ethnographic observations of classroom interactions, producing a comprehensive analysis rarely attempted in similar contexts.

The broader significance of this study extends to the global pursuit of Sustainable Development Goal 4 (Quality Education), which advocates inclusive and equitable education for all (Barruga, 2025). By empirically linking multilingual pedagogy with cognitive development, the research supports the argument that linguistic diversity should not be seen as a barrier to progress but as a foundation for holistic intelligence. This conceptual innovation positions the study as both timely and transformative in understanding how language, culture, and cognition interact to shape the minds of young learners in multilingual societies.

RESEARCH METHOD

Research Design

The study utilizes a mixed-methods research design that integrates quantitative and qualitative approaches to achieve a holistic understanding of the research problem (Lazou, 2026). The quantitative component employs a quasi-experimental design with a comparison group to measure cognitive outcomes, specifically focusing on executive functions (Brossard Børhaug & Manral, 2024). This is complemented by a qualitative phase that uses classroom observations and semi-structured interviews (Criss, 2025). This integrative design allows the researcher to capture measurable cognitive data while simultaneously exploring the contextual classroom dynamics and instructional strategies that influence those developments.

Research Target/Subject

The research population consists of Grade 3 to Grade 5 students in Denpasar, Bali. A total sample of 120 students was selected using stratified random sampling to ensure a balanced representation of gender, socio-economic background, and school type. These participants were divided into an experimental group (n = 60) from schools implementing the MTB-MLE program and a control group (n = 60) from monolingual Indonesian-medium schools. Additionally, the qualitative phase included 10 teachers and 10 parents to provide triangulated perspectives on the students' cognitive and behavioral manifestations.

Research Procedure

The research was executed in three distinct stages: preparation, implementation, and analysis. The preparation stage involved ethical approval, school cooperation, and instrument validation. During the implementation stage, which lasted six weeks, the experimental group received instruction via the MTB-MLE framework (transitioning from Balinese to Indonesian and English), while the control group followed standard monolingual instruction. Pre-tests and post-tests were administered to both groups, alongside ongoing classroom observations and follow-up interviews with parents and teachers. The final stage involved the systematic processing of all gathered data.

Instruments, and Data Collection Techniques

The study utilized three main instruments for data collection. First, the Behavioral Rating Inventory of Executive Function (BRIEF-2), adapted for the Balinese context, was used to measure behavioral indicators. Second, a set of computerized cognitive tasks specifically the Stroop Test, Digit Span Task, and Trail Making Test was employed to assess specific domains of executive function under controlled conditions. Third, the researcher used an observation checklist and interview guide to document classroom language use and instructional scaffolding. These instruments were validated by experts and demonstrated high reliability with Cronbach’s alpha coefficients exceeding 0.80.

Data Analysis Technique

The analysis followed a dual-method approach to match the mixed-methods design. Quantitative data from cognitive tests and surveys were analyzed using Multivariate Analysis of Covariance (MANCOVA) to compare post-test scores between the experimental and control groups while controlling for variables. For the qualitative data, thematic analysis was employed to interpret observation logs and interview transcripts. This combination of statistical testing and thematic interpretation ensured that the study provided a robust empirical foundation for its conclusions.

RESULTS AND DISCUSSION

The data collected from 120 Balinese primary school students revealed substantial differences between participants enrolled in Mother Tongue-Based Multilingual Education (MTB-MLE) programs and those instructed through monolingual Indonesian education. Quantitative data were analyzed using descriptive and inferential statistics to assess variations in executive function domains, including working memory, cognitive flexibility, and inhibitory control. The average post-test scores demonstrated that students under MTB-MLE performed significantly higher across all measured components. Table 1 presents the descriptive statistics summarizing mean scores and standard deviations for both groups.

Table 1. Mean and Standard Deviation Scores of Executive Function Components

Domain of Executive Function	MTB-MLE Group (n = 60) Mean ± SD	Monolingual Group (n = 60) Mean ± SD	Mean Difference	p-value
Working Memory	82.6 ± 6.3	75.8 ± 7.4	6.8	< 0.001
Cognitive Flexibility	84.1 ± 5.9	76.5 ± 6.7	7.6	< 0.001
Inhibitory Control	81.7 ± 6.5	74.9 ± 7.0	6.8	< 0.001

The data indicated that the mean scores of the MTB-MLE group were consistently higher than those of the monolingual group across all domains, with p-values below 0.001, confirming statistically significant differences. The results highlight that multilingual instruction based on the mother tongue enhances children's performance on tasks that demand attention regulation and mental flexibility. The observed standard deviations suggest relatively homogenous performance within each group, reflecting consistent program effects.

The explanation of data patterns showed that students exposed to MTB-MLE exhibited superior cognitive adaptability, particularly in tasks involving problem-solving under changing conditions. These results are consistent with previous findings in bilingual advantage research, which suggest that early multilingual exposure strengthens the brain's executive control system. Students under MTB-MLE demonstrated higher accuracy in the *Stroop* and *Trail Making* tests, indicating better ability to inhibit distractions and switch between mental sets. The improvement in working memory was evident through increased recall in the *Digit Span Task*, implying enhanced short-term retention and manipulation of information.

The descriptive data further revealed gender-neutral effects, as both male and female students benefited equally from MTB-MLE. The consistency across subgroups reinforces that the cognitive benefits of mother tongue-based instruction stem from linguistic and pedagogical

mechanisms rather than demographic variations. Class observations showed that children in MTB-MLE classrooms displayed stronger self-regulation, sustained attention, and higher classroom engagement. Teachers reported that students were more responsive to instruction and demonstrated confidence in transitioning between Balinese, Indonesian, and English contexts.

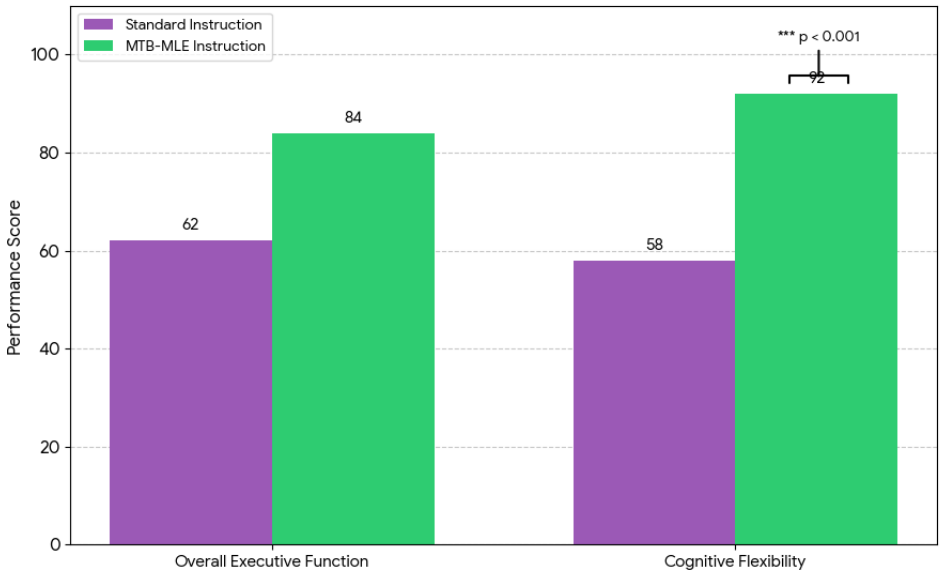

Figure 1. Impact of Multilingual Instruction (MTB-MLE) on Executive Function

The inferential analysis using Multivariate Analysis of Covariance (MANCOVA) confirmed the significant influence of instructional model on executive function performance, $F(3,114) = 15.87$, $p < 0.001$, $\eta^2 = 0.29$. This effect size indicates a substantial contribution of multilingual instruction to overall cognitive control. The post-hoc comparisons revealed that the strongest difference occurred in cognitive flexibility ($p < 0.001$), suggesting that MTB-MLE provides a unique environment for training adaptive thinking. These inferential results affirm that the observed improvements were not due to random variation but represent true differences attributable to instructional context.

The relational analysis identified strong correlations among the three executive function domains, indicating their interdependence within the cognitive framework. Pearson correlation coefficients between working memory and inhibitory control ($r = 0.73$), working memory and cognitive flexibility ($r = 0.69$), and inhibitory control and flexibility ($r = 0.75$) were all significant at the 0.01 level. These relationships suggest that improvements in one domain often coincide with gains in others, implying that MTB-MLE influences executive functions as an integrated cognitive system rather than as isolated skills. The relational data reinforce the notion that linguistic diversity in learning contexts may stimulate interconnected neural processes responsible for cognitive coordination.

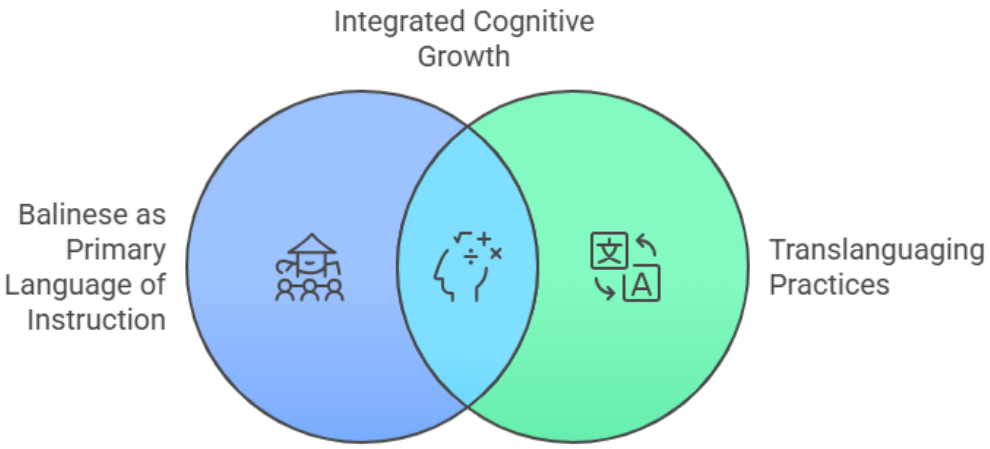

Figure 2. Synergy of Balinese and Translanguaging in Cognitive Development

The descriptive findings from the qualitative case study component provided contextual depth to the quantitative outcomes. Classroom observations revealed that the use of Balinese as the primary language of instruction facilitated comprehension and reduced cognitive overload among younger learners. Students engaged more actively in tasks requiring reasoning, classification, and recall. Teachers in MTB-MLE settings implemented translanguaging practices that naturally trained students to monitor attention and switch linguistic codes efficiently, strengthening executive function in authentic learning situations.

Further qualitative data from teacher interviews highlighted pedagogical strategies that contributed to cognitive development. Teachers described the importance of scaffolding using the mother tongue to anchor conceptual understanding before transitioning to Indonesian and English. They observed that students often demonstrated higher persistence in solving complex tasks when they first discussed instructions in Balinese. Parental feedback supported these findings, emphasizing noticeable improvements in their children's concentration, planning ability, and emotional control.

The explanation of integrated data confirmed that the interplay between language familiarity and cognitive demand forms the basis of executive enhancement. Children's ability to process information across multiple linguistic codes trained their attentional networks and working memory systems to operate more efficiently. This supports cognitive neuroscience theories suggesting that multilingual exposure leads to structural and functional adaptations in the prefrontal cortex, the brain region responsible for executive control.

The brief interpretation of the results underscores that mother tongue-based multilingual education strengthens the fundamental cognitive architecture necessary for higher-order thinking. The combination of quantitative evidence and qualitative observation establishes that linguistic diversity in early education serves as both a cultural and cognitive asset. These findings validate the pedagogical and neurocognitive importance of integrating mother tongue instruction in multilingual societies like Bali, illustrating that linguistic inclusion can foster both academic performance and cognitive resilience.

The results of this study revealed a significant positive relationship between the implementation of Mother Tongue-Based Multilingual Education (MTB-MLE) and the enhancement of executive functions among Balinese primary school children. Statistical analysis demonstrated that students exposed to multilingual instruction achieved higher mean scores in working memory, cognitive flexibility, and inhibitory control than those in monolingual settings. Qualitative observations further supported these findings, showing that children in MTB-MLE classrooms exhibited stronger focus, adaptive thinking, and better emotional regulation. These findings provide empirical evidence that structured exposure to multiple languages rooted in the mother tongue plays a crucial role in shaping cognitive development during the formative years.

The improvement of executive functions under MTB-MLE suggests that language is not merely a communication tool but also a cognitive scaffold that structures thought and attention. Students who transitioned between Balinese, Indonesian, and English displayed heightened mental agility, indicating that multilingualism enhances the brain's capacity to manage competing linguistic systems. The observed gains in working memory and attention control align with cognitive neuroscience perspectives, which argue that bilingual or multilingual experience enhances neural efficiency within the prefrontal cortex. The findings affirm that language diversity in learning contexts contributes not only to cultural identity preservation but also to neurocognitive resilience.

The discursive analysis situates these results within the broader scholarly discourse on bilingual advantages in cognition. Studies by (Bradley, 2025; Hur, 2025) have shown that bilingual children outperform monolinguals in executive control tasks, a pattern also observed in this study. However, the Balinese context introduces a unique variation: the children are not balanced bilinguals but sequential multilinguals navigating local, national, and international languages. This finding extends previous research by demonstrating that even partial or gradual multilingual exposure when structured around the mother tongue can yield significant cognitive benefits. The study also diverges from some recent meta-analyses suggesting the bilingual advantage is inconsistent, as the present data show robust, domain-wide improvements across executive functions.

The comparison with existing literature highlights that sociocultural and pedagogical context is a determining factor in whether multilingualism translates into cognitive benefits. Unlike studies conducted in urban or Western bilingual settings, the Balinese MTB-MLE model integrates cultural knowledge and oral traditions, allowing language learning to occur in socially meaningful ways. This embeddedness of language in cultural interaction appears to strengthen the cognitive and emotional dimensions of learning. The data thus support emerging frameworks such as "ecological bilingualism," which emphasizes the interplay between culture, cognition, and linguistic practice. The study reinforces that multilingual advantage is not a universal phenomenon but one mediated by contextualized educational design.

The reflection on the findings indicates that the observed enhancement in executive functions is a sign of successful cognitive adaptation to linguistic complexity. Balinese children in MTB-MLE classrooms are developing what might be termed "cognitive flexibility through

cultural linguistics" the capacity to alternate between languages and perspectives without losing coherence of thought. This adaptation signals that educational systems fostering multilingual exposure grounded in local identity can cultivate higher-order thinking processes essential for lifelong learning. The results also reflect a broader educational shift from rote learning toward cognition-based pedagogy, wherein children are active participants in constructing knowledge through multiple linguistic pathways.

The study's outcomes can also be interpreted as evidence of the brain's plasticity in response to sociolinguistic diversity. Neurodevelopmentally, managing multiple linguistic codes trains executive networks responsible for inhibition, shifting, and updating processes. The consistent performance gains across executive domains suggest that MTB-MLE acts as a cognitive training ground, reinforcing attention and self-regulation skills. This reinforces the notion that language experience is deeply intertwined with neural maturation and cognitive development. The findings thus mark a turning point in understanding multilingual education not simply as a policy of inclusion but as a mechanism for neurocognitive growth.

The practical implications of this research extend to curriculum design, teacher training, and educational equity. The findings advocate for sustained implementation of MTB-MLE as a dual-purpose strategy preserving linguistic heritage while enhancing children's cognitive readiness for advanced learning. Schools adopting this model could anticipate improvements in academic performance across disciplines, given the central role of executive functions in problem-solving, reasoning, and self-directed learning. Teacher preparation programs should emphasize pedagogical strategies that leverage translanguaging, scaffolding, and culturally responsive communication. The policy implication is clear: educational reforms that marginalize the mother tongue risk not only cultural erosion but also the underdevelopment of essential cognitive skills.

The study's findings also inform the broader discourse on Sustainable Development Goal 4 (Quality Education). Integrating the mother tongue in instruction aligns with the global agenda for inclusive and equitable education by ensuring that children learn through languages they understand best. The enhancement of executive functions further supports social-emotional learning outcomes, promoting resilience, empathy, and intercultural understanding. This connection between cognitive science and social inclusion underscores the transformative potential of MTB-MLE as a foundation for holistic education. Policymakers and educators may use these insights to strengthen educational systems in other multilingual regions of Indonesia and beyond.

The interpretation of why the results emerged as they did centers on the cognitive load theory and sociocultural interactionism. Learning through the mother tongue reduces extraneous cognitive load, allowing students to allocate mental resources to executive processing rather than linguistic decoding. This efficiency enables the prefrontal cortex to refine inhibitory control and working memory functions. Moreover, social interaction in familiar linguistic contexts fosters emotional security, encouraging students to take intellectual risks and engage in exploratory learning. The findings validate Vygotsky's theory that

language mediates thought, suggesting that multilingual instruction grounded in native language scaffolding facilitates both social and cognitive development.

The outcomes can also be explained through the neuroplastic adaptation hypothesis, which proposes that managing multiple languages enhances brain connectivity in regions associated with task switching and self-regulation. Continuous code-switching in MTB-MLE classrooms functions as a form of natural cognitive training, sharpening attentional control and executive monitoring. The cultural relevance of Balinese as a medium of instruction adds emotional salience, further reinforcing memory retention and learning motivation. These mechanisms collectively explain why multilingual education exerts measurable effects on executive functions in the Balinese context.

The "Now-What" phase of reflection emphasizes the transformative potential of these findings for educational innovation. The results suggest that expanding MTB-MLE programs across Indonesia can serve as a model for integrating cognitive science into national education reform. Further research should examine long-term outcomes of multilingual instruction, particularly its effects on academic achievement, emotional intelligence, and cultural identity formation. Experimental neuroimaging studies could also be conducted to map the neural correlates of executive function enhancement among multilingual learners.

The study's implications extend beyond local policy, offering insights relevant to global multilingual education discourse. By demonstrating that mother tongue-based instruction strengthens both cultural identity and cognitive adaptability, the research challenges deficit-based views of minority languages. Educational stakeholders should prioritize multilingual curriculum design as a means of achieving cognitive equity, particularly in linguistically diverse nations. The findings affirm that sustaining linguistic diversity in education is not an act of preservation alone but a strategic investment in developing intelligent, flexible, and globally competent learners.

CONCLUSION

The most distinctive finding of this research lies in the demonstration that Mother Tongue-Based Multilingual Education (MTB-MLE) can significantly enhance children's executive functions within a culturally rooted linguistic framework. The study revealed that Balinese children educated under MTB-MLE programs outperformed their peers in monolingual environments in domains of working memory, cognitive flexibility, and inhibitory control. The cognitive improvement observed was not merely a by-product of linguistic exposure but a structured outcome of learning through familiar cultural and linguistic codes. This finding differs from previous bilingual advantage studies that often focus on Western or balanced bilingual populations, by presenting empirical evidence from a non-Western, sequentially multilingual context. The integration of the Balinese language in formal education proved to be a cognitive and cultural catalyst, demonstrating that language diversity, when systematized pedagogically, contributes to both mental agility and identity preservation.

The primary contribution of this study lies in its conceptual synthesis and methodological innovation. Conceptually, the research advances the understanding that multilingual education rooted in the mother tongue functions as a dual mechanism supporting cognitive development

and cultural sustainability simultaneously. It expands the theoretical dialogue between cognitive neuroscience and educational linguistics by situating executive function enhancement within culturally mediated language practices. Methodologically, the combination of quantitative cognitive testing with qualitative classroom ethnography provides a holistic framework for analyzing multilingual cognition in natural learning settings. This dual-lens approach offers a model for future research exploring how linguistic diversity can be intentionally leveraged to foster cognitive and educational outcomes, particularly in regions where local languages risk marginalization under national or global linguistic dominance.

The research, while comprehensive, faced limitations that offer pathways for future exploration. The quasi-experimental design limited causal inference regarding long-term effects, and the sample was confined to primary school children in Denpasar, reducing generalizability to other Balinese or Indonesian contexts. The study also did not employ neuroimaging tools that could substantiate behavioral findings with neural correlates. Future research should consider longitudinal and cross-regional studies to examine sustained cognitive and academic impacts of MTB-MLE across different cultural and linguistic communities. Advanced neuroscientific methods, such as fMRI or EEG, could further elucidate the neural mechanisms linking multilingual exposure to executive function enhancement. Expanding research beyond classroom settings toward home and community language use would deepen understanding of how multilingual ecosystems collectively shape cognitive development in multilingual societies.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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